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Orbital Collector Concept

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1.0 BRIEF ABSTRACT

This is a concept for a system that can perform most aspects of recycling/manufacturing in zero-g & low-g space environments. The system consists primarily of a rotating arm that provides artificial gravity, power, data, and mechanical connections to different modules designed for individual aspects of recycling/manufacturing. The modules are designed to contain the materials being processed, thereby preventing the system from generating external debris during recycling/manufacturing. This system is designed to complement the abilities of the Orbital Workshop (see NTR 1662994822).

2.0 CONTRIBUTORS

Innovators
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Andrew Schnell – MSFC ST40
Luke Scharber – MSFC ER41

3.0 PROBLEM/OBJECTIVE

3.1 Objective

Generate a system capable of recycling components/scraps down to forms useful for manufacturing and to perform some manufacturing on-orbit.

3.2 Problem

The material lifecycle is not complete for orbital systems. Components are manufactured on earth and sent into space for their functional life. At the end of their life, they are either abandoned in orbit or are deorbited instead of recycling their materials. Currently orbital recycling and manufacturing technologies are lacking and there are no other options. Additionally, current ground manufacturing and recycling technologies don't work on orbit for several reasons:

1. Gravity is used for nearly all ground recycling technologies
2. Gravity is used for many manufacturing technologies
3. Significant quantities of debris are generated for most manufacturing and recycling technologies. This isn't a problem on earth, but debris generation on orbit is a catastrophic hazard.
4. Most recycling and manufacturing techniques require significant human interaction, which presents a danger for astronauts (EVA's) and is very expensive.
5. Many manufacturing and recycling techniques use fluids, which is impossible on-orbit without pressurized systems.
6. Significant waste is generated during recycling and manufacturing. This waste needs dedicated storage on-orbit.
7. Power requirements are fairly high for manufacturing and recycling, which is difficult to obtain on-orbit.
8. Manufacturing and recycling mechanisms often jam and require servicing. On-orbit the ability to service systems is near impossible.

4.0 DESCRIPTION

4.1 Purpose

The collector is one of two systems necessary (see NTR 1662994822) to perform orbital recycling and manufacturing. This system focuses on performing most aspects of recycling/manufacturing (steps 1, 4B, 4C, 4D, 4E in Figure 1) except for deconstructing large scale assemblies (Figure 1 Step 4A) and manufacturing large scale systems (Figure 1 Step 1). This system primarily consists of an arm (Fig. 2 A) that rotates slowly on an axis with a mechanism to extend/retract to join latching mechanisms (Fig. 2 H) & engaging/disengaging recycling and manufacturing modules (Fig. 2 D, E, F, G). The slow rotation generates slight artificial gravity which can move material of different forms and enables the use of ground recycling/manufacturing technologies. The system is modular to allow for different manufacturing/recycling/storage systems to perform different tasks. The modules identified today include storage (Figure 3), shredder (Figure 4), pulverizer (Figure 5), powder bed additive manufacturing (Figure 6), sorting (to be described in a future NTR), wire forging (Figure 7), dispensing (Figure 8), material test (figure 6), and disposal. Modularity allows further development of technologies and enables servicing/disposal of jammed/failed systems if necessary. This system (with the appropriate modules) is capable of recycling components/scraps of small/moderate size to forms desirable for manufacturing. The main target for this system is structural metals, but other materials can be reused with development of the appropriate modules. This system is likely reasonably scalable with upper limits tied to payload size. Note that this system is not capable of breaking down or manufacturing large systems, see NTR 1662994822. This system would be easily adapted to use on low gravity missions to the Moon and Mars (Figure 16).

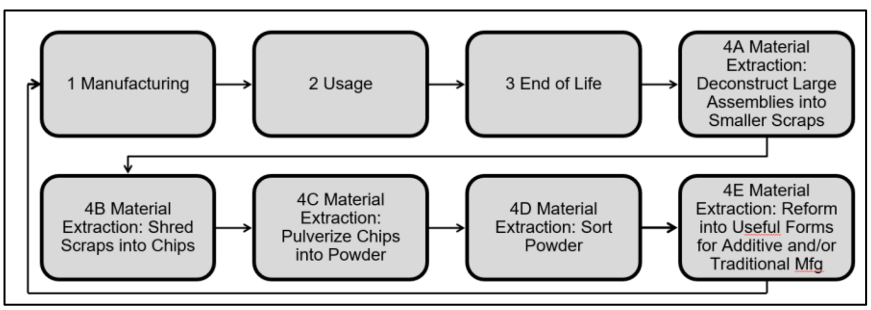

Figure 1: Material Lifecycle

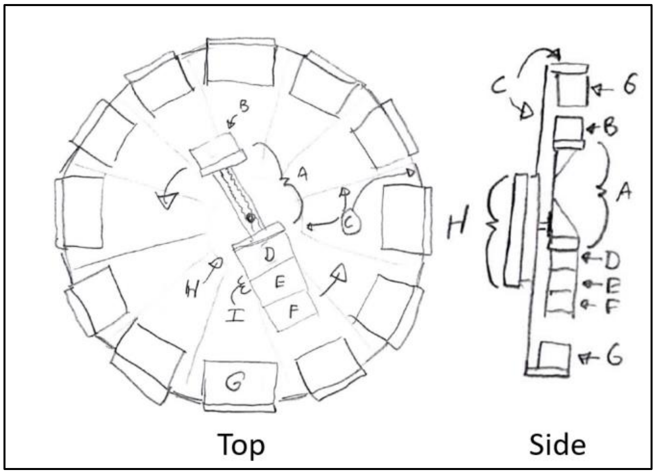

Figure 2: Collector Overall Design

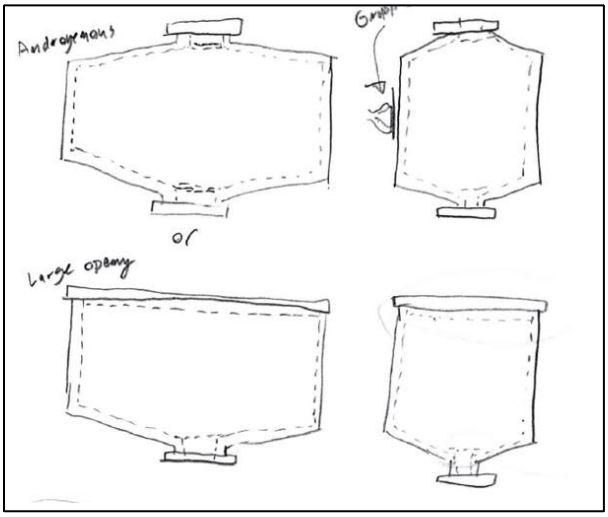

Figure 3: Notional Container Module Design

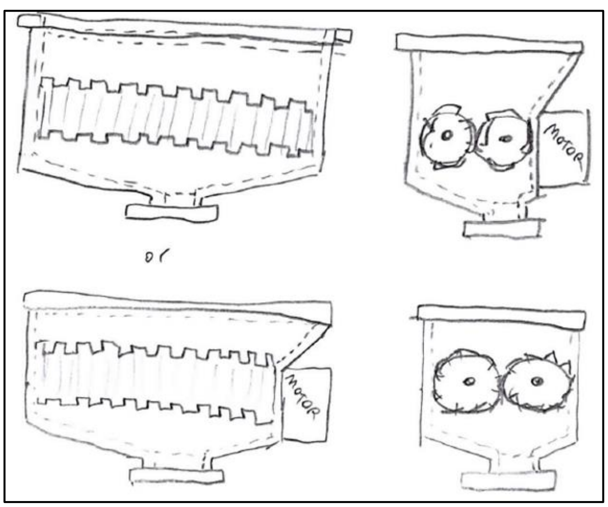

Figure 4: Notional Shredder Module Design

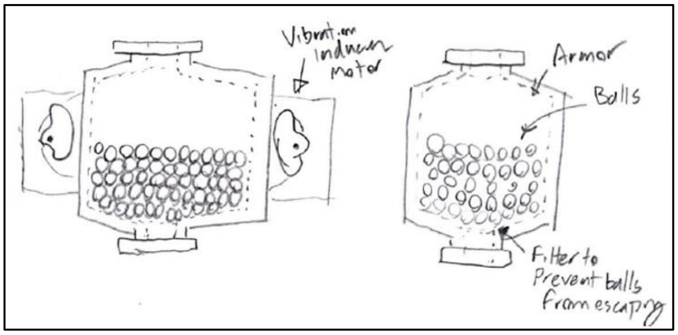

Figure 5: Notional Pulverizer Module Design

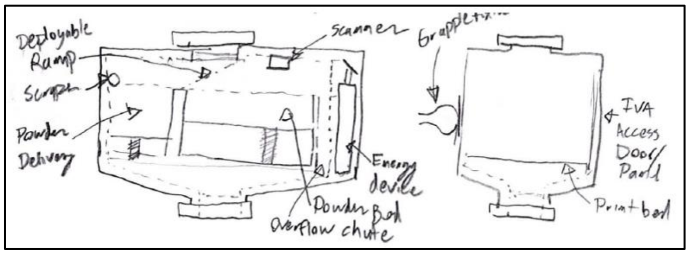

Figure 6: Notional Powder Bed Additive Manufacturing Module Design

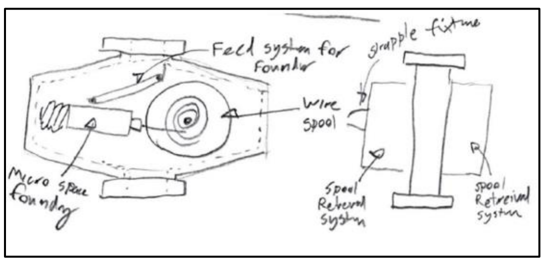

Figure 7: Notional Wire Forging Module Design

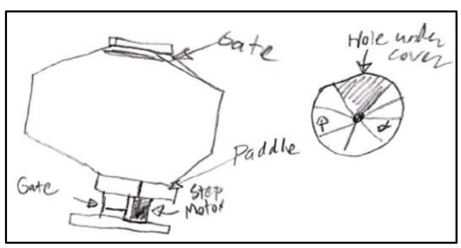

Figure 8: Notional Dispensing Storage Module Design

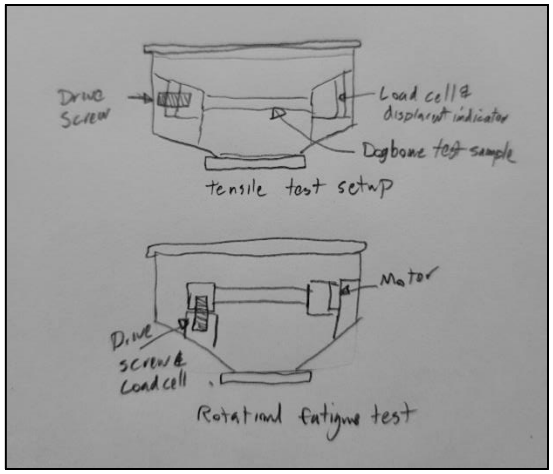

Figure 9: Notional Material Test Module Design

5.0 DESIGN DESCRIPTION

5.1 Collector

The collector is a single assembly with multiple modules either in storage or in use (Figure 2). The main assembly is a circular structure with attachments for modules in a circular array (Figure 2 G). At the center of the circle is a mechanical arm (Figure 2 A) that can rotate about the circle's axis and extend/retract radially. The arm can engage/disengage modules on both sides of the module being manipulated, up to three modules at a time (Figure 2 D, E, F). This enables stacking of modules so that appropriate containers and recycling/manufacturing modules can be integrated. These modules are powered and to be supplied with limited control while operating. The details of the connection between modules is to be designed (notional design in Figure 11). This rotating arm also enables storage of modules in the circular array of the main assembly (Figure 2 G). Because the circular storage array is not powered, there is potential for a collapsible launch configuration (Figure 17). Depending on storage array diameter and module size, a second manipulator (Figure 2 B) can be used to double throughput and/or act as a counterweight.

5.2 Modules

The modules are designed to be androgynous and have common attachments so that they can connect to each other or the main assembly arm/storage (Figure 11). The modules will need some sort of latching/fastening system to connect them to each other and the arm/storage points. The modules & containers are hollow with openings at each end. Each module will need gates to close at each end so that material will not escape when not in use (Figure 10). The modules that serve a purpose beyond material storage will require external power & mechanisms to perform those functions. For example, a shredding module (Figure 4) will look very similar to a storage module (Figure 3), but will have shredding wheels on the interior and the appropriate drivetrain to go with it. Note that the exterior of these modules may need some sort of system so that they can be manipulated by an arm or astronaut outside of the collector (Figure 3 includes a notional grapple connection).

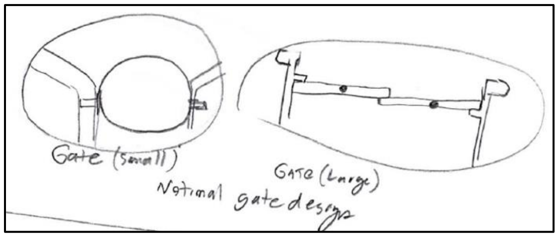

Figure 10: Notional Module Gate Opening Designs

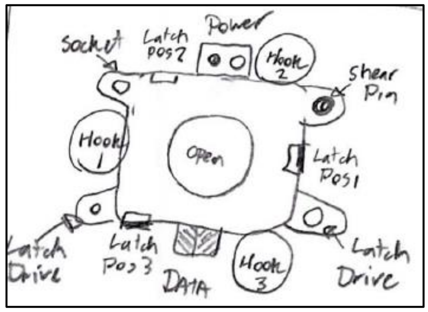

Figure 11: Notional Module Interface Design

5.3 Example of process

1. System receives a container of scraps from a defunct system (e.g. ISS).
2. That container is stacked with a shredder and an empty container. Order from axis center outwards is: container of parts, shredder, empty container (Figure 12).
3. The internal connections between each module are opened.
4. The system is rotated such that artificial gravity feeds the parts into the shredder and then the empty container.
5. The shredder is powered and smaller scraps are collected in the bottom container.
6. Steps 2-5 are repeated with the scrap container -> pulverizer -> dispenser container (Figure 13).
7. Steps 2-5 are repeated with dispenser container -> sorter -> empty containers
8. Repeat step 7 for any desired material.

Multiple options can be pursued here:

- 9A. Metals can be reformed into wire for other additive manufacturing systems (Figure 15).
- 9B. Powder bed additive manufacturing module can be used to build small components (Figure 14).
- 9C. Materials unable to be used can be disposed.
- 9D. Materials can be stored for later use.

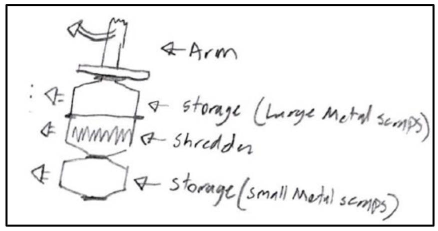

Figure 12: Shredder Operational Configuration

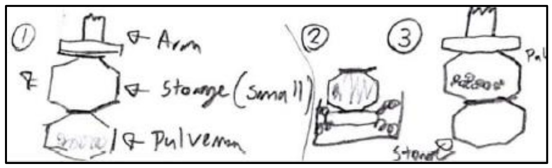

Figure 13: Pulverizer Operational Configuration

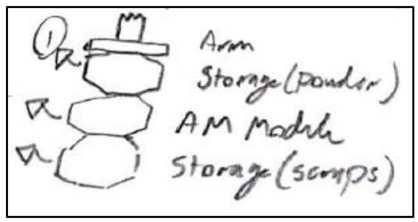

Figure 14: AM Module Operational Configuration

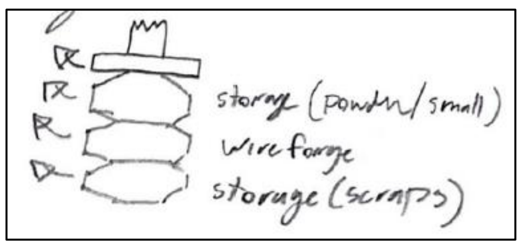

Figure 15: Wire Forge Operational Configuration

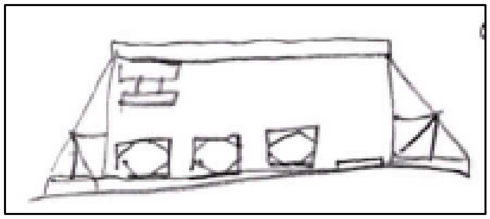

Figure 16: Notional Low Gravity Configuration

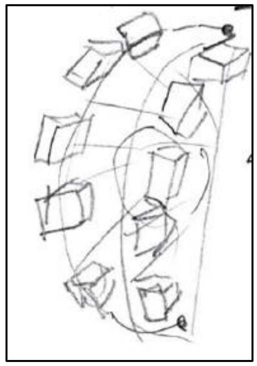

Figure 17: Potential Launch Configuration

5.4 Module designs

1. Storage container (Figure 3) - hollow box with gates at each the top and bottom inside of the connection/interface. The walls will be sloped such that material won't get stuck as easily when moving material to other modules. A design may exist with a larger opening for use on other systems.
2. Shredding module (Figure 4) - Similar to a storage container but with shredding wheels on the interior and a drivetrain on the exterior.
3. Pulverizer module (Figure 5) - Similar to a storage container but with ball mill balls on the interior and a vibration mechanism on the exterior. Note that this design can potentially be operated in a dedicated location with vibration isolation features.
4. Wire forge module (Figure 7) - Similar to a storage container but with a wore forming system on the interior.
5. Dispensing storage container (Figure 8) - Similar to a storage container but with a paddle mechanism to slowly distribute material on the interior and a drivetrain on the exterior.
6. Powder Bed Additive Manufacturing Module (Figure 6) - Similar to a storage container but with additive manufacturing system on the interior.
7. Disposal Storage Container - Similar to a storage container (Figure 3) but made to be lightweight and cheap so that it can be disposed of.
8. Material Test Module – Similar to a storage container, but with a tensile test machine and rotating fatigue test machine for performing tests on reformed material forms developed on-orbit.
9. Sorter module - Will be included in another NTR.

6.0 UNIQUE OR NOVEL FEATURES

- These techniques have not been adapted to orbital use, so the overall system of performing manufacturing and recycling on-orbit is novel.
- Using a rotating arm to provide low gravity to feed and operate recycling/manufacturing technologies is novel. Note that moving irregularly shaped & small particle materials is very difficult/impossible without gravity. Note that shredding, powder bed AM, sorting, and other technologies cannot function without gravity.
- Using modularity to store materials and perform recycling/manufacturing is novel. Note that this allows removal of jammed modules for servicing or deorbiting. Note that this also allows for future technologies to be developed and integrated after initial deployment.
- Using the rotating/extending arm to connect/disconnect modules is novel. Note that this allows modules to be integrated in different orders for different purposes/processes.
- The overall design of interconnected modules is novel in that the scrapped components, processed material, and final manufactured parts are always contained.
- Using the ISS as a target and a power source is novel.

7.0 COMMERCIALIZATION POTENTIAL

Other companies and government agencies could benefit greatly from orbital recycling and manufacturing technologies.

- The main commercialization potential is the ability to recycle space debris and decommissioned systems (including ISS, spent stages, spacecraft, satellites, and service modules) to save on launch costs & raw material costs as the recyclable materials would no longer need to be launched (note that some systems & fuel would likely need to be launched and integrated on-orbit until orbital manufacturing technologies mature).
- New designs and structures unable to survive earth launch environments would be able to be manufactured on-orbit, opening new avenues for technologies on-orbit.
- Technologies developed for on-orbit use can also be adapted easily to be used on the moon and other planets.
- Recycling technologies are also necessary for reusing scrap materials that are created through manufacturing.
- If debris poses an unacceptable hazard, space debris can be captured and recycled.
- In-situ repairs become possible for deep space missions, increasing reliability while decreasing payload needs.

Additionally, there is significant financial savings to be had in targeting the ISS materials before decommissioning. A rough estimate puts 1 billion dollars of structural materials based on low end launch cost estimates.

8.0 DEGREE OF TECHNICAL SIGNIFICANCE

Modification to Existing Technology

9.0 STATE OF DEVELOPMENT

Conceptual

10.0 RELATED TECHNOLOGIES

- Workshop NTR #1662994822
- Sorter NTR #1663685477